

Appendix D

Revisions to April 2005 Bacteria TMDL for Christina River Basin

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On April 8, 2005, the United States Environmental Protection Agency Region III established Total Maximum Daily Loads (TMDLs) for bacteria and sediment for the portions of the Christina River Basin listed on the Clean Water Act Section 303(d) lists for the Commonwealth of Pennsylvania and the State of Delaware. Additional information has become available for combined sewer overflow (CSO) and National Pollutant Discharge Elimination System (NPDES) discharges that prompted this revision to the April 2005 TMDLs. The updated information is described in this appendix.

D.1 Event Mean Concentrations for Wilmington CSO Discharges

Following the establishment of the Christina River Basin bacteria and sediment TMDLs, the City of Wilmington and Delaware Department of Natural Resources and Environmental Control completed a storm-monitoring program. The goal of the storm-monitoring program was to collect nutrient and bacteria data from four storm events to establish characteristic concentrations for the CSO discharges in the City of Wilmington. Two storm events had been completed prior to the April 2005 TMDL. After April 2005, the monitoring data from two additional storm events were available. This proposed TMDL revision incorporates data from the four storm events to establish updated event mean concentrations (EMCs) for the Wilmington CSO discharges as shown in Table D-1.

Table D-1. Revised EMCs for City of Wilmington CSOs

CSO ID	EMC April 2005 TMDL (cfu/100mL)	EMC for Revised TMDL (cfu/100mL)
CSO 4b	56,117	34,917
CSO 25	235,333	57,885
CSO 3	113,833	121,635
All other CSOs	113,833	45,888

The data from the individual storm events are summarized in Table D-2. The revised event mean concentrations were calculated using a geometric mean of the data associated with a given CSO. The event mean concentrations for the April 2005 TMDL were calculated using an arithmetic mean of the data associated with a particular CSO. For the April 2005 TMDL, data from the 11th Street Pumping Station were used to establish EMCs for CSO3 and all other CSOs except for CSO 4b, and CSO 25. For the revised TMDL, data from the 11th Street Pumping Station was used to establish the EMC only for CSO 3 because of its close proximity to the pumping station. The EMCs for the other CSOs were calculated as the geometric mean from the combined storm monitoring data from CSO 4b and CSO 25.

Stormwater runoff sometimes exhibits high pollutant concentrations during the initial stages of a storm. This is referred to as the “first flush.” Examination of the CSO storm

monitoring data in Table D-2 did not indicate any strong first-flush tendency. Larger concentrations were just as likely to occur several hours into the storm event rather than at the beginning. Also, in many of the storms, the concentrations were relatively constant over time. Due to the absence of any definitive evidence in the monitoring data, the first-flush phenomenon was not included in this analysis. Event-mean concentrations were considered appropriate for characterizing the mass loadings from the CSO outfalls.

Table D-2. Wilmington CSO *enterococci* storm monitoring data

CSO4b		CSO25		CSO3 (11th St. Pump Station)	
Date	cfu/100mL	Date	cfu/100mL	Date	cfu/100mL
10/27/2003 11:40	90,000	10/27/2003 11:00	230,000	10/27/2003 11:20	280,000
10/27/2003 12:10	90,000	10/27/2003 11:30	70,000	10/27/2003 11:50	400,000
10/27/2003 12:40	110,000	10/27/2003 12:00	40,000	10/27/2003 12:10	130,000
10/27/2003 13:10	110,000	10/27/2003 12:30	80,000	10/27/2003 12:50	140,000
10/27/2003 13:40	130,000	10/27/2003 13:30	30,000	10/27/2003 13:20	130,000
10/27/2003 14:10	50,000	10/27/2003 14:00	50,000	10/27/2003 13:50	110,000
12/17/2003 09:00	25,000	12/17/2003 08:45	18,000	12/17/2003 08:50	36,000
12/17/2003 09:30	18,000	12/17/2003 09:15	1,500,000	12/17/2003 09:20	32,000
12/17/2003 10:00	20,000	12/17/2003 09:45	100,000	12/17/2003 09:50	24,000
12/17/2003 10:30	15,000			12/17/2003 10:20	27,000
12/17/2003 11:00	11,000	11/04/2004 13:20	27,000	12/17/2003 10:50	23,000
12/17/2003 11:30	4,400	11/04/2004 13:50	27,000	12/17/2003 11:20	34,000
		11/04/2004 14:20	25,000		
11/04/2004 13:33	33,000	11/04/2004 14:50	42,000	11/04/2004 13:25	370,000
11/04/2004 14:03	26,000			11/04/2004 13:55	360,000
11/04/2004 14:33	39,000	10/08/2005 07:55	70,000	11/04/2004 14:25	380,000
11/04/2004 15:03	36,000	10/08/2005 08:25	218,182	11/04/2004 14:55	290,000
11/04/2004 15:33	34,000	10/08/2005 08:55	96,396	11/04/2004 15:25	400,000
		10/08/2005 09:25	101,802	11/04/2004 15:55	340,000
		10/08/2005 09:55	61,818		
		10/08/2005 10:15	510		
		10/08/2005 10:25	236,364		
EMC	34,917		57,885		121,635
EMC (4b and 25)	45,888				

D.2 Summary of Annual Baseline and TMDL CSO *Enterococci* Loads

A summary of the baseline and TMDL CSO *enterococci* loads grouped by Environmental Fluid Dynamics Code (EFDC) model grid cell location is presented in Table D-3. The locations of the CSO discharges and the EFDC model grid cells are shown in Figure D-1. Note that CSO 31 discharges to Shellpot Creek, which flows into the Delaware River and is outside the Christina River Basin, therefore it is not included in the CSO load totals for the baseline and TMDL columns in Table D-3. The following CSOs were assigned zero flow (i.e., 100% load

reduction) for the TMDL allocation: 4b, 4c, 4f, 12, 14, 15, 18, 20, and Rockford Road based on information provided by the City of Wilmington. A comparison of the baseline and TMDL *enterococci* loads for the April 2005 TMDL and this revised TMDL is presented in Table D-4.

Table D-3. Average annual baseline and TMDL CSO loads grouped by EFDC grid cell

Location - EFDC [I,J]	CSO ID numbers	Baseline (cfu/yr)	TMDL (cfu/yr)	Percent Reduction
Little Mill Creek. - [44,55]	27, 28	1.120E+14	2.652E+13	76.32%
Little Mill Creek - [45,55]	29	4.379E+13	1.037E+13	76.32%
Christina River - [52,13]	5, 6, 7, 11, 12, 13, 30	1.730E+14	5.961E+13	65.55%
Christina River - [53,13]	9a, 10, 14, 15, 16, 17	1.725E+14	3.745E+13	78.29%
Christina River - [55,13]	9c	8.585E+12	4.384E+11	94.89%
Brandywine Creek - [54,16]	18	5.377E+10	0.000E+00	100.00%
Brandywine Creek - [54,17]	3, 4a, 4b, 4c, 4d, 19, 20, 21a, 21b, 21c	3.340E+14	6.301E+13	81.14%
Brandywine Creek - [54,18]	4e, 4f, 22b, 22c, 23, 24	1.342E+14	1.157E+14	13.83%
Brandywine Creek - [54,20]	25, 26	2.109E+14	7.586E+13	64.04%
Brandywine Creek - [54,21]	RR	9.951E+12	0.000E+00	100.00%
Shellpot Creek - [57,15] *	31	4.247E+13	2.991E+13	29.59%
Total CSO load		1.199E+15	3.889E+14	67.57%

*CSO31 not included in total CSO load since it discharges outside of Christina River Basin

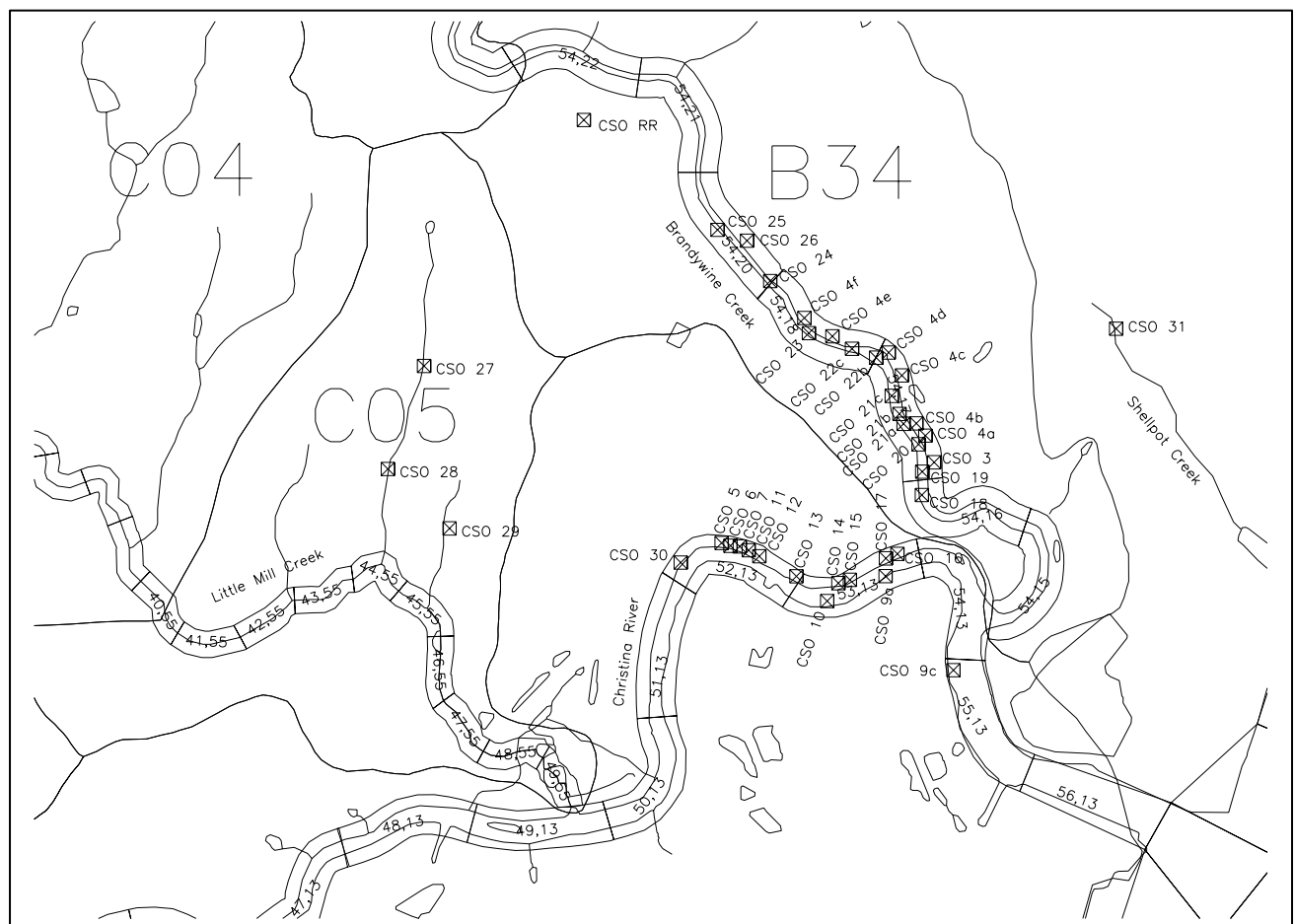


Figure D-1. Location of CSO discharges in relation to EFDC model grid cells

Table D-4. Comparison of revised CSO *enterococci* average annual loads with April 2005 TMDL

Location - EFDC [I,J]	CSO ID numbers	Revised TMDL		April 2005 TMDL	
		Baseline (cfu/yr)	WLA (cfu/yr)	Baseline (cfu/yr)	WLA (cfu/yr)
Little Mill Creek. - [44,55]	27, 28	1.120E+14	2.652E+13	2.778E+14	4.167E+13
Little Mill Creek - [45,55]	29	4.379E+13	1.037E+13	1.086E+14	1.630E+13
Christina River - [52,13]	5, 6, 7, 11, 12, 13, 30	1.730E+14	5.961E+13	4.293E+14	6.439E+13
Christina River - [53,13]	9a, 10, 14, 15, 16, 17	1.725E+14	3.745E+13	4.279E+14	6.419E+13
Christina River - [55,13]	9c	8.585E+12	4.384E+11	2.130E+13	3.195E+12
Brandywine Creek - [54,16]	18	5.377E+10	0.000E+00	1.334E+11	2.001E+10
Brandywine Creek - [54,17]	3, 4a, 4b, 4c, 4d, 19, 20, 21a, 21b, 21c	3.340E+14	6.301E+13	6.652E+14	9.977E+13
Brandywine Creek - [54,18]	4e, 4f, 22b, 22c, 23, 24	1.342E+14	1.157E+14	3.330E+14	4.995E+13
Brandywine Creek - [54,20]	25, 26	2.109E+14	7.586E+13	8.538E+14	1.281E+14
Brandywine Creek - [54,21]	RR	9.951E+12	0.000E+00	2.468E+13	3.703E+12
Shellpot Creek - [57,15] *	31	4.247E+13	2.991E+13	1.054E+14	1.580E+13
Total CSO load		1.199E+15	3.889E+14	3.142E+15	4.713E+14

*CSO31 discharges outside of Christina River Basin

D.3 Addition of Little Mill Creek to EFDC Model

Little Mill Creek receives loading from CSOs 27, 28, and 29 located in subbasin C05. In the April 2005 TMDL, Little Mill Creek was not explicitly included in the EFDC model domain for the *enterococci* bacteria analysis. Instead, the flow and load from these three CSOs were assigned to Christina River grid cell [49,13]. In this revised TMDL, 10 grid cells representing Little Mill Creek were added into the model domain. CSO 27 and CSO 28 discharge to EFDC grid cells [44,55] and CSO 29 discharges to grid cell [45,55] as indicated in Table D-3 and shown in Figure D-1.

D.4 Updated NPDES Information

The Hydrologic Simulation Program Fortran (HSPF) and EFDC models were calibrated using information for the 1994-1998 period, including NPDES facilities that were in existence at that time. The NPDES facilities were updated prior to the April 2005 TMDL. Additional information on the NPDES discharges has become available since issuance of the April 2005 TMDL and has been incorporated into this revised TMDL. The changes to the NPDES discharges are listed in Table D-5.

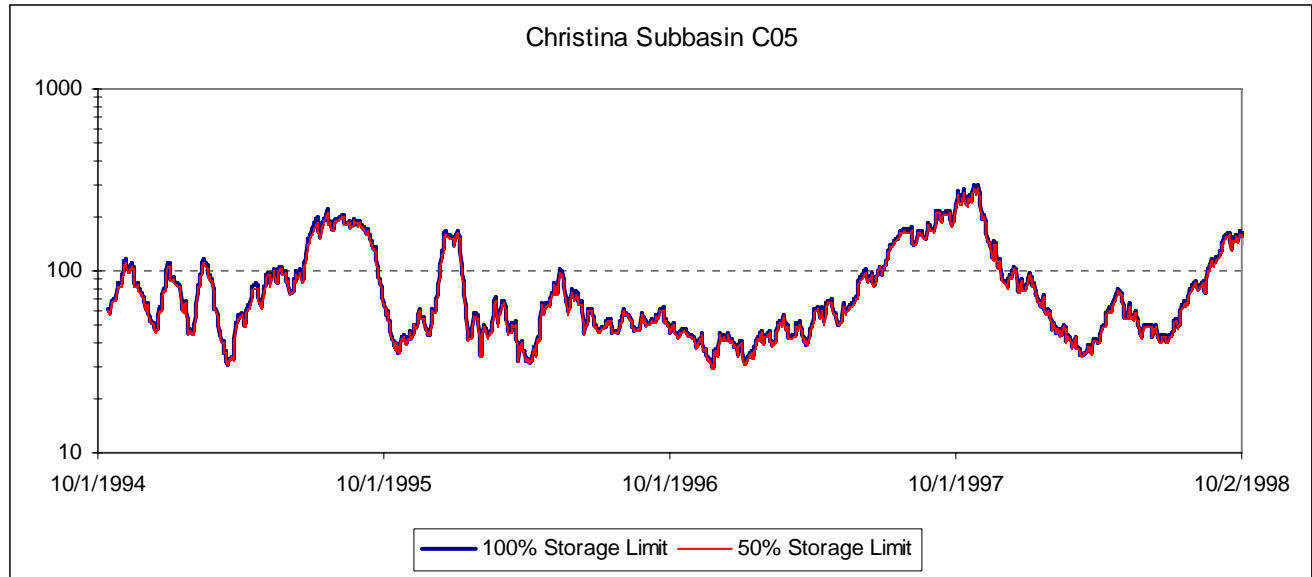
Table D-5. List of updated NPDES information for Christina River Basin

NPDES Permit	HSPF subbasin	Name	Description of Change
PA0012416	B03	PA American Water (Rock Run)	New owner (previously owned by Coatesville)
PA0011568-001	B05	ISG Plate LLC (Sucker Run, W. Br. Brandywine Cr.)	New owner (previously owned by Lukens Steel)

NPDES Permit	HSPF subbasin	Name	Description of Change
PA0011560-016	B05	ISG Plate LLC (Sucker Run, W. Br. Brandywine Cr.)	New owner (previously owned by Lukens Steel)
PA0055492	B10	Andrew and Gail Woods (Indian Run)	New owners (previously owned by John and Jane Topp)
PA0051365	B11	PA American Water (E. Br. Brandywine Cr.)	New owner (previously owned by West Chester Area Municipal Authority)
PA0026531	B13	Downingtown Area WWTP (E. Br. Brandywine Cr.)	Flow increase from 7.134 to 7.500 mgd
PA0244031	B16	Chadds Ford Township (Brandywine Cr.)	Replaces PA0047252 (Pantos Corp.). Flow increase from 0.07 to 0.15 mgd
PA0055085	B16	Nancy Winslow (Brandywine Cr.)	Active during 1994-98 calibration period. No longer exists.
PA0036161	B20	Lincoln Crest MHP (Buck Run)	Active during 1994-98 calibration period. No longer exists.
PA0053937	B29	William and Patricia Kratz (Broad Creek)	New owners (previously owned by Ralph and Gayla Johnson)
PA0056952	W04	Sun Company, Inc. (E. Br. White Clay Cr.)	Active during 1994-98 calibration period. No longer exists.
PA0052019	W04	Avon Grove Trailer Court (E. Br. White Clay Cr.)	Active during 1994-98 calibration period. No longer exists.
PA0029343	W06	Chatham Acres (E.Br. White Clay Cr.)	Active during 1994-98 calibration period. No longer exists.
PA0057720-001	R01	Sunny Dell Foods, Inc. (W. Br. Red Clay Cr.)	Flow increase from 0.05 to 0.072 mgd

D.5 Sensitivity to *Enterococci* Storage Limit

During dry periods, *enterococci* bacteria accumulate at a specified rate on the land surface and eventually reach a maximum accumulated limit, called the storage limit in the HSPF model. A rain event following a dry period then washes the accumulated bacteria from the land surfaces into the receiving streams. During model calibration, the *enterococci* storage limit was set to 15 times the accumulation rate based on previous modeling experience. As a sensitivity test, the storage limit was reduced by 50% to evaluate whether this parameter would have a significant impact on model results. The test indicated the resulting *enterococci* concentrations would be reduced by only about 3% on average as a result of a 50% reduction in *enterococci* storage limit. The time series of model concentrations for the baseline run in HSPF subbasin C05 (Little Mill Creek) indicates that both the 100% and 50% storage limit scenarios are nearly identical (see Figure D-2). Since the model was relatively insensitive to a large reduction in the storage limit parameter, no change to that parameter was made for this revised TMDL model application.



D.6 EFDC Model Calibration Results

Following the updates to the CSO loading described in section D.1, the addition of Little Mill Creek described in section D.3, and the changes to the NPDES facilities described in section D.4, the EFDC *enterococci* bacteria model was recalibrated. Model-data agreement was visually assessed by use of probability distributions for the six monitoring stations listed in Table D-6. The model-data probability distribution graphics are presented in Figures D-3 through D-8. The model probability distribution was derived using the daily average results from the four-year calibration period (October 1, 1994, through October 1, 1998) and was comprised of 1461 data points. The probability distributions for the monitoring stations were based on available monitoring data from July 1986 through November 1998. Sample sizes ranged from 35 data points at station 106291 to 125 data points at station 104011 (see Table D-6). Considering the discrepancy between the model and observed sample sizes, the model results compare reasonably well with the observations.

Table D-6. Locations of Monitoring stations used for EFDC model calibration

Monitoring Station	Sample Size	EFDC grid cell [I,J]	Description
104011	125	[43,55]	Brandywine Creek, footbridge in Brandywine Park
106281	37	[54,20]	Little Mill Creek at Atlantic Avenue
106291	35	[55,13]	Christina River, railroad bridge near Port of Wilmington
106011	117	[53,13]	Christina River, US Rt. 13 at Third Street bridge
106021	116	[47,13]	Christina River, Rt. 141 drawbridge in Newport, DE
106031	97	[34,13]	Christina River at Smalleys Dam

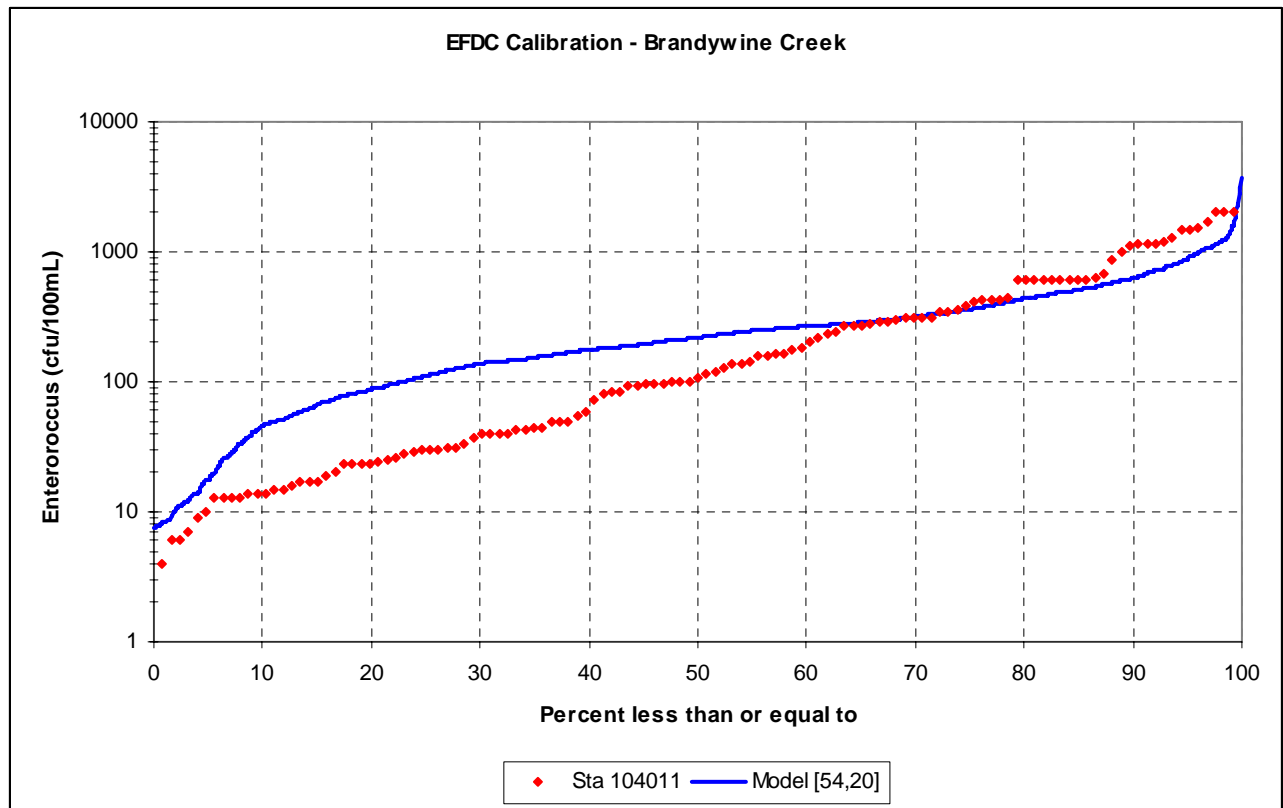


Figure D-3. Model-data probability distribution at station 104011, Brandywine Creek

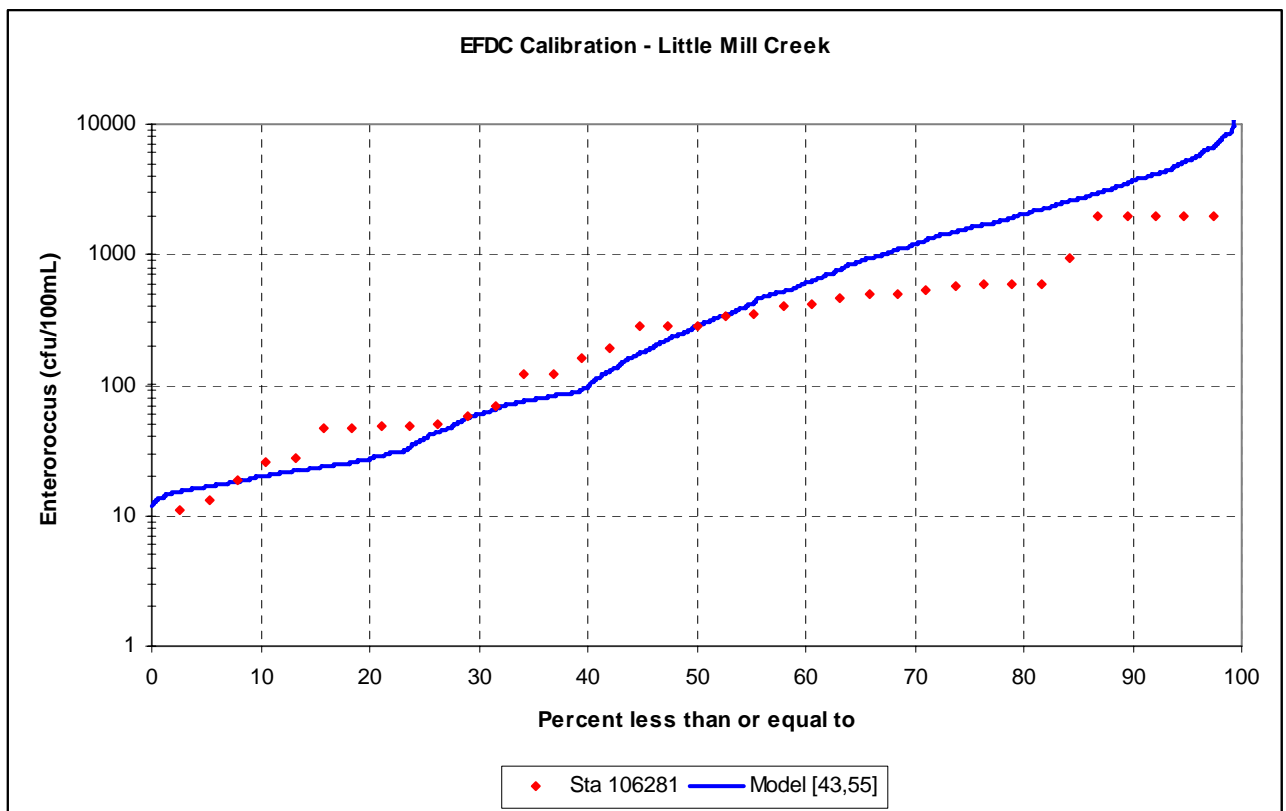


Figure D-4. Model-data probability distribution at station 106281, Little Mill Creek

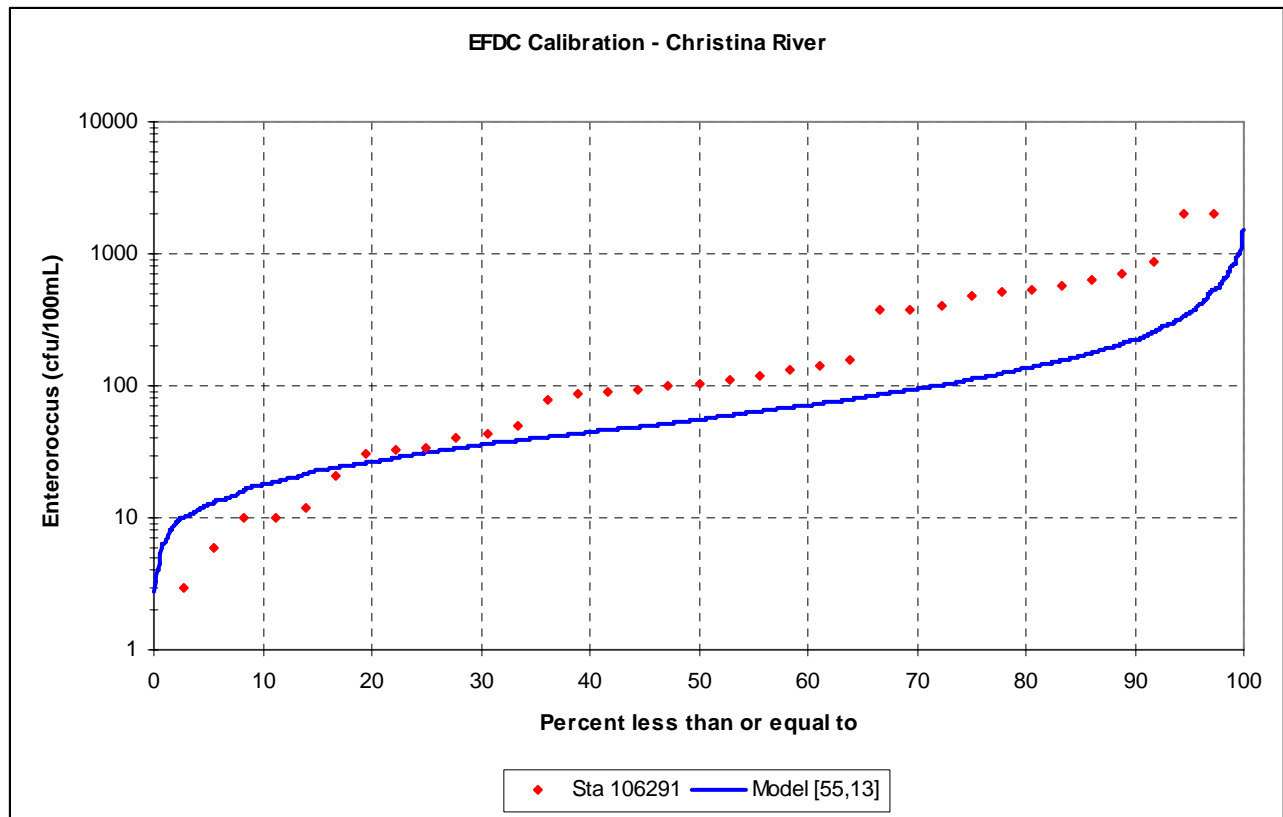


Figure D-5. Model-data probability distribution at station 106291, Christina River

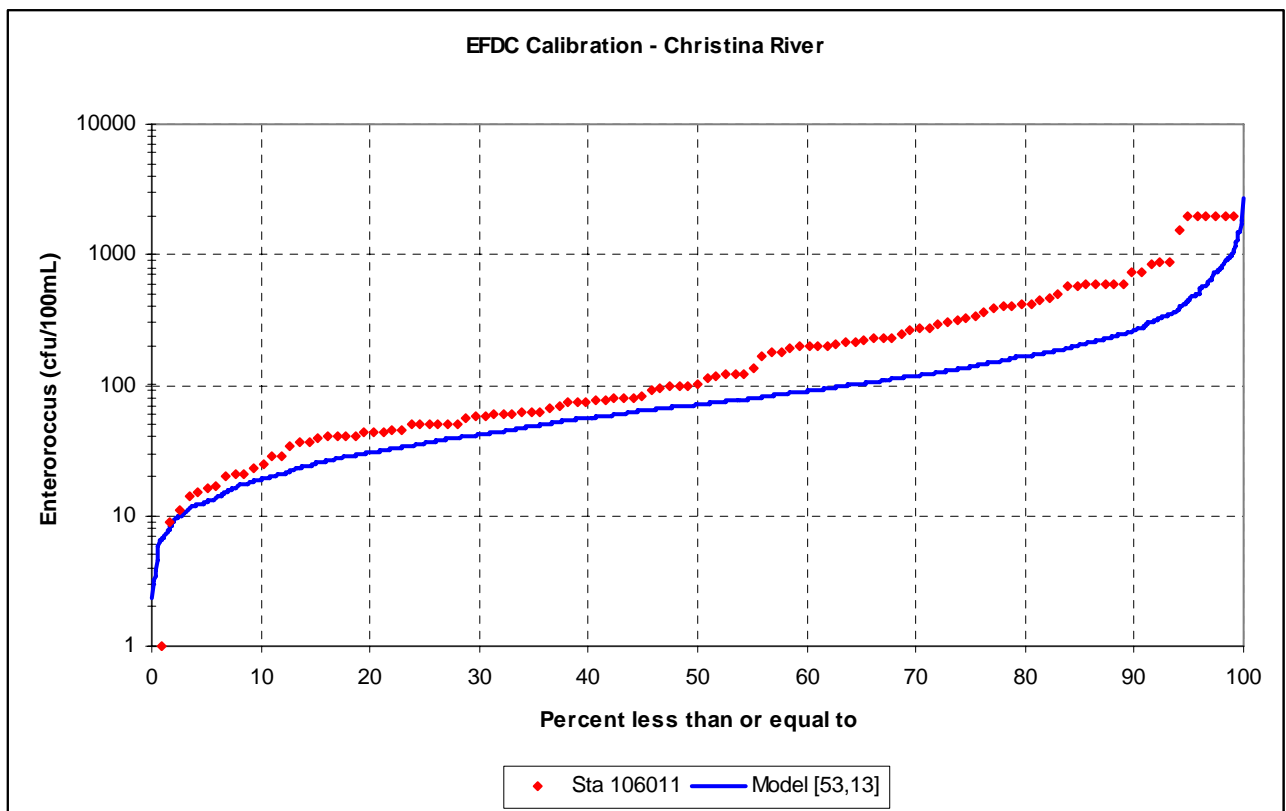


Figure D-6. Model-data probability distribution at station 106011, Christina River

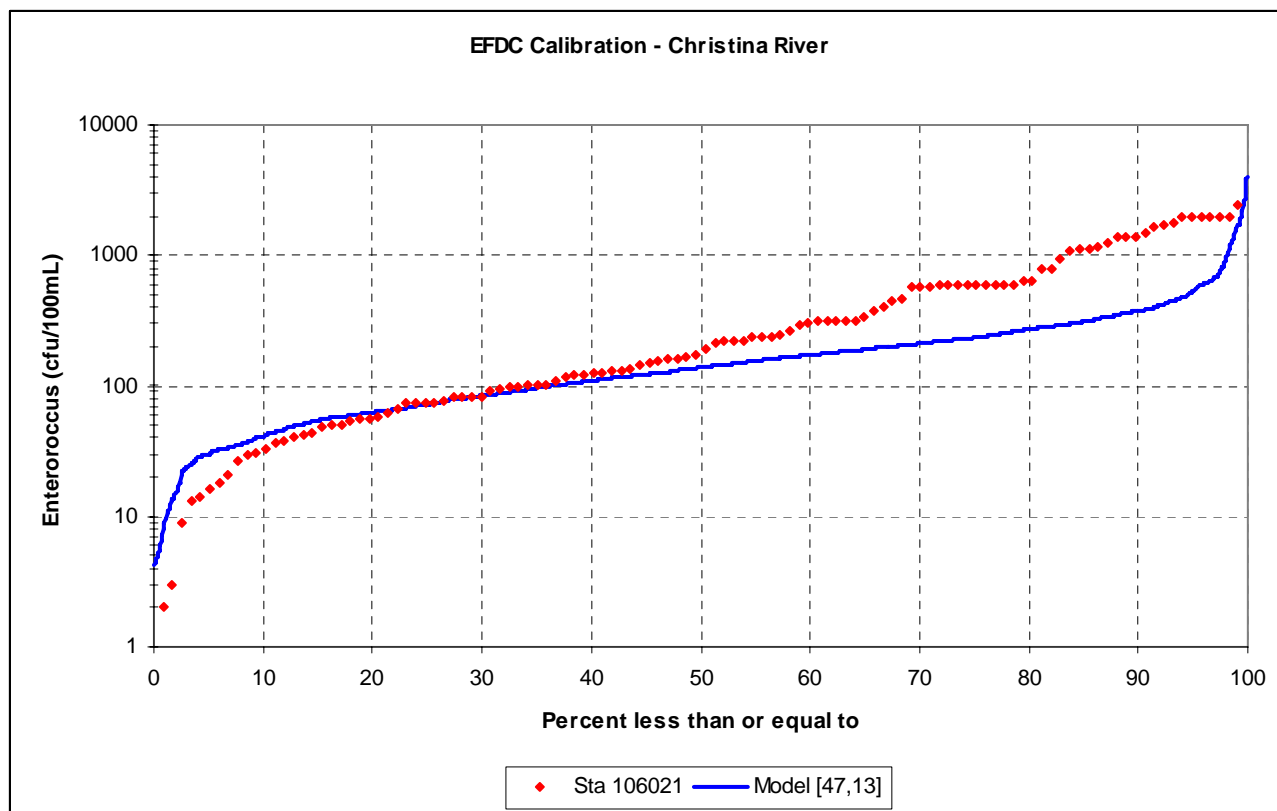


Figure D-7. Model-data probability distribution at station 106021, Christina River

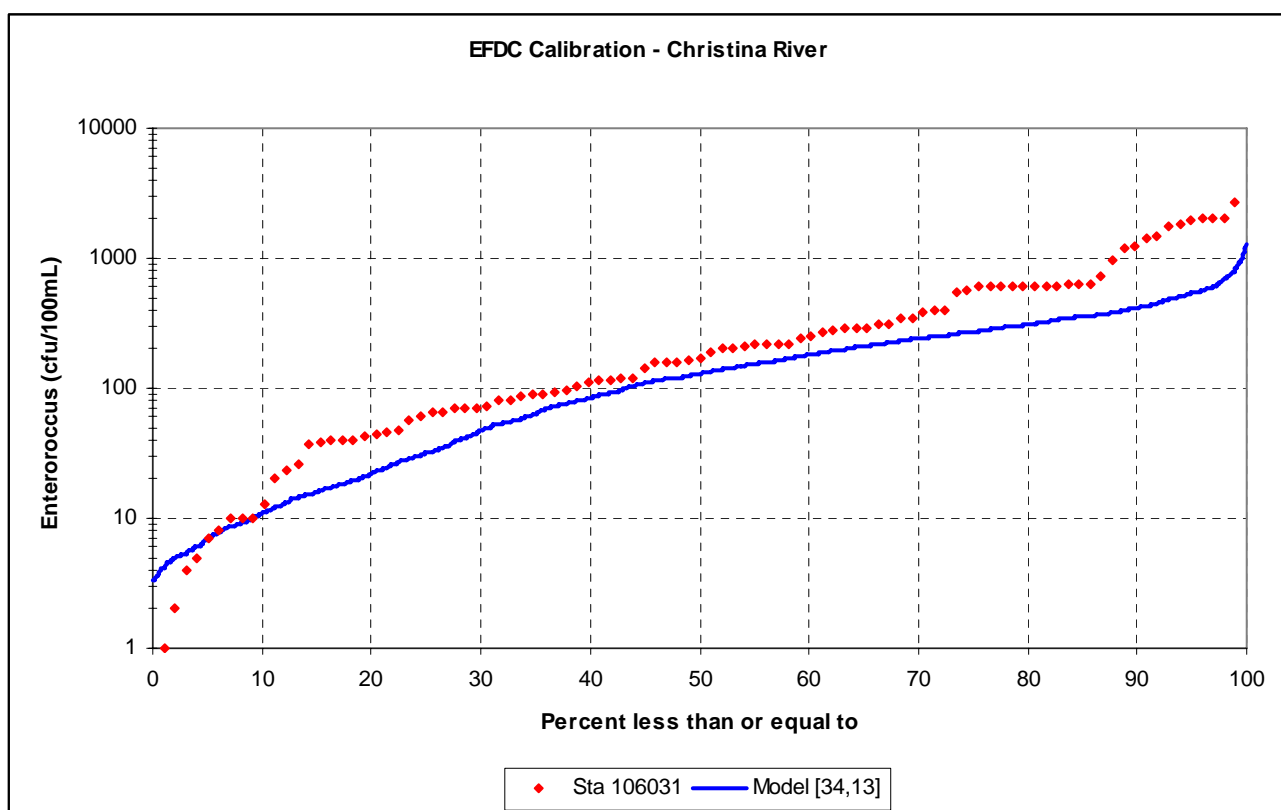


Figure D-8. Model-data probability distribution at station 106031, Christina River

D.7 Baseline and TMDL *Enterococci* Model Results

The EFDC model results for the baseline and revised *enterococci* TMDL are shown in Figures D-9 to D-14. These graphs represent the longitudinal transect of the three impaired water segments (Christina River, lower Brandywine Creek, and Little Mill Creek). The river mile notation for each stream reach is defined in Table D-7. The model results in Figures D-9, D-10, and D-11 represent the maximum of the running 30-day geometric mean concentration at each model grid cell along a given transect. The 30-day geometric mean *enterococci* water quality standard (100 cfu/100mL) is also shown on each graph.

Table D-7. Stream reaches included in EFDC *enterococci* bacteria model

Stream Reach	River Mile at Mouth	River Mile at Upstream Extent
Christina River	74.2	89.6
Brandywine Creek	76.3	80.4
Little Mill Creek	79.8	82.6

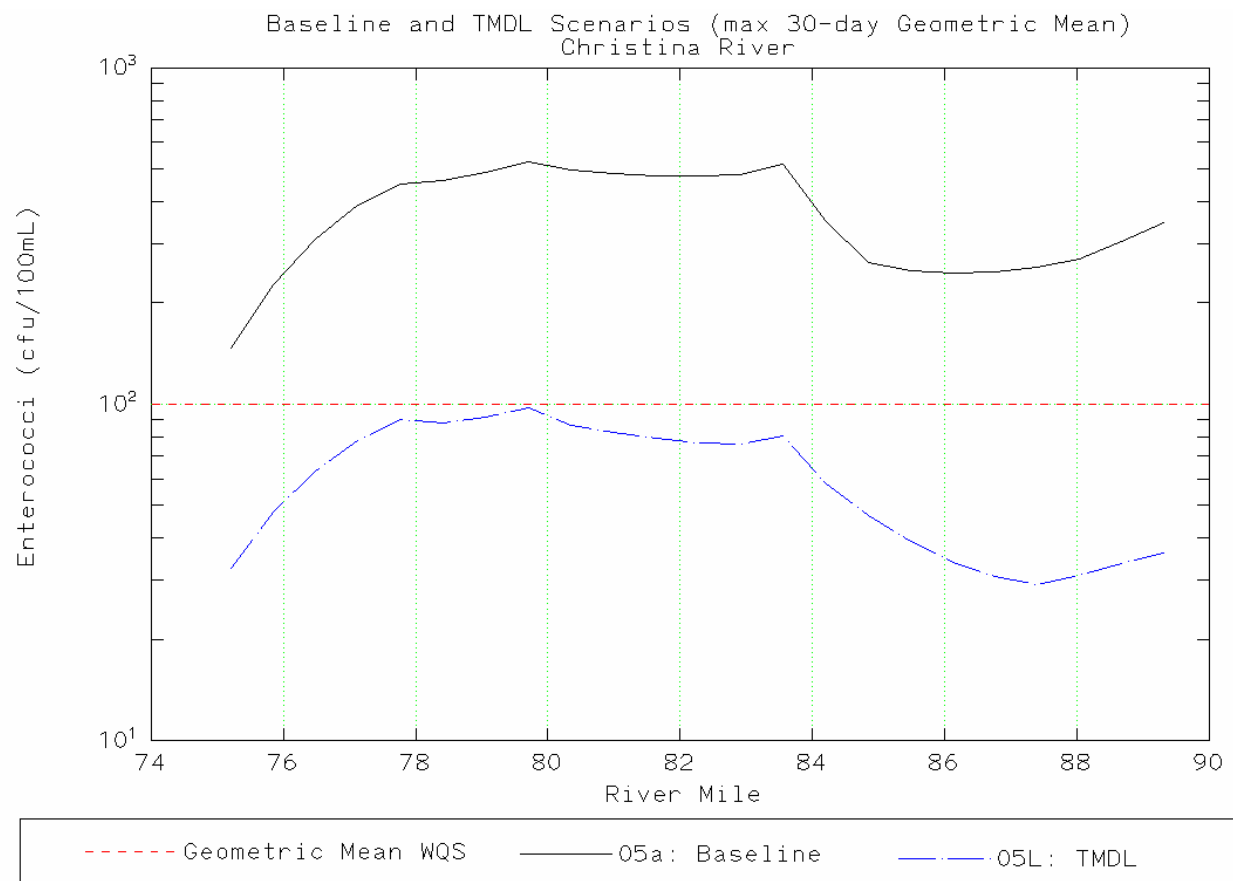


Figure D-9. Christina River, comparison to 30-day geometric mean WQS

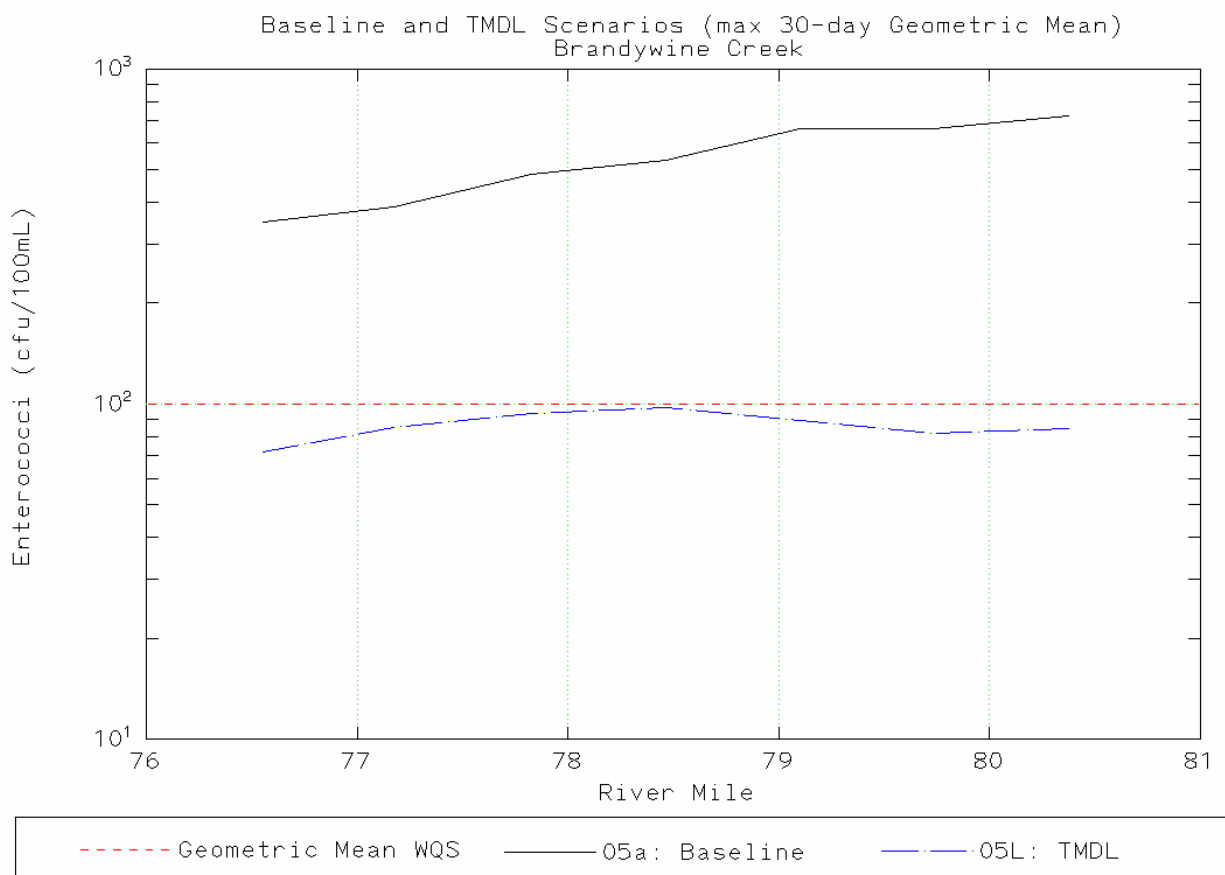


Figure D-10. Brandywine Creek, comparison to 30-day geometric mean WQS

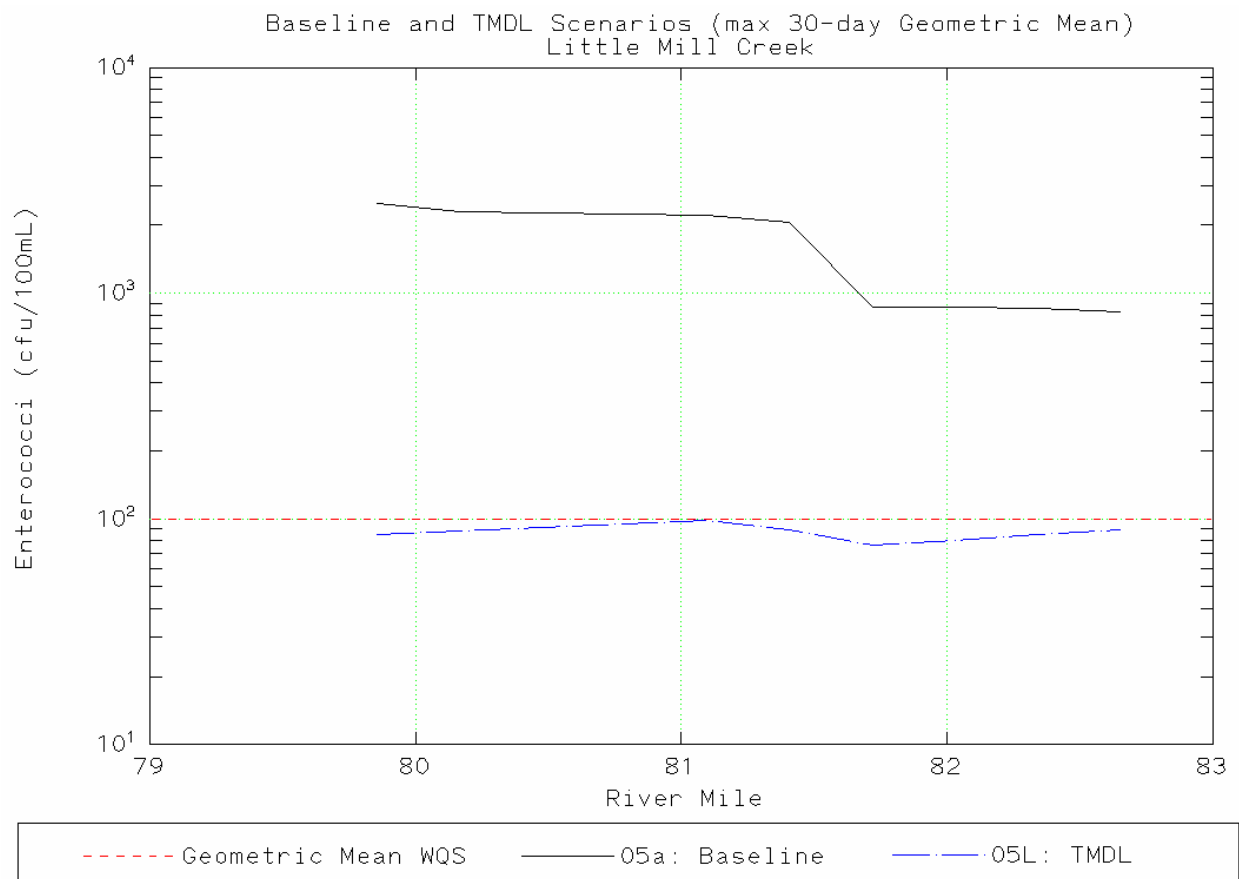


Figure D-11. Little Mill Creek, comparison to 30-day geometric mean WQS